FRACTAL CHARACTERIZATION OF MULTITEMPORAL REMOTE SENSING DATA

Dale A. Quattrochi*
National Aeronautics and Space Administration
Global Hydrology and Climate Center
SD60
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812 USA

Charles W. Emerson
Department of Geography
Western Michigan University
Kalamazoo, Michigan 49008 USA

Nina Siu-Ngan Lam
Department of Geography and Anthropology
Louisiana State University
Baton Rouge, Louisiana 70803 USA

Hong-lie Qiu
Department of Geography
California State University, Los Angeles
Los Angeles, California 90032-8222 USA

*Corresponding author. E-mail address: dale.quattrochi@msfc.nasa.gov

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1. Scale and Multiscaled Imagery

Scale is an "innate" concept in geographic information systems. It is recognized as something that is intrinsic to the capture, storage, manipulation, analysis, modeling, and output of space and time data within a GIS purview, yet the relative meaning and ramifications of scaling spatial and temporal data from this perspective remain enigmatic. As GISs become more sophisticated as a product of more robust software and more powerful computer systems, there is an urgent need to examine the issue of scale, and its relationship to the whole body of spatiotemporal data, as imparted in GISs. Scale is fundamental to the characterization of geo-spatial data as represented in GISs, but we have relatively little insight on how to measure the effects of scale in representing data that are acquired in different formats and exist in varying spatial, temporal, and radiometric configurations. Moreover, the complexities associated with the integration of multiscaled data sets in a multitude of formats are exacerbated by the confusion of what the term "scale" is from a multidisciplinary perspective. "Scale" takes on significantly different meanings depending upon one's disciplinary background and spatial perspective which can lead to substantial confusion in the input, manipulation, analysis, and output operations (Quattrochi, 1993). Hence, we must begin to look at the universality of scale and begin to develop the theory, methods, and techniques necessary to advance knowledge on the "Science of Scale" across all disciplines that use GISs.

Questions of scale in remote sensing and spatial statistics combine both the issues of level of aggregation of the observation (i.e., the resolution of the sensor) and the extent of the observation (the "footprint" of the data and the times of data collection). Aggregation is analogous to the concepts of geostatistical support (Dungan, 1998) and the related Modifiable Areal Unit Problem (Openshaw and Taylor, 1981; Fotheringham and Wong, 1991). Spatial autocorrelation and sensor resolution interact in often unpredictable ways when images are resampled to a common resolution (Bian and Butler, 1999) and combined with data obtained from different sensors or data represented in other measurement frameworks such as vector polygons.

The extent of the observation relates to an alternate definition of scale from the commonly accepted cartographic definition. In this sense, a "large" scale study would cover a large part of the earth's surface and would require spatially (and perhaps temporally) extensive imagery. Cartographically, this study would be depicted in "small" scale, generalized maps.

Another aspect of scale is that of the operational domain (Cao and Lam, 1997). Earth surface processes operate at characteristic spatial domains, such as global scale patterns in upper-level winds, synoptic scale meteorological phenomena that occur over several hundred kilometers (e.g., fronts), mesoscale patterns in rainfall over a city, and local scale eddies around a building. The hierarchical pattern and structure of many landscape processes (Batty and Xie, 1996) require knowledge of how processes observed using imagery having a given resolution and spatial extent operate over distances and time periods relevant to the study.

To adequately address the complexities of scale, we must not only have a better understanding of what scale *is*, and what its dynamics *are*, but we must also develop innovative and robust methods or "tools" to adequately manipulate, analyze and convey the nature of multi-scaled data (in both space and time). This is particularly true with the advent of high-resolution remote sensing platforms, such as the NASA (Earth Observing

System) EOS suite of sensors (see MTPE EOS, 1999), where large quantities of remote sensing data are becoming available at many different space, time, and radiometric resolutions. These data will be combined with other raster and vector data sets in an Integrated GIS (IGIS) framework (Star and Estes, 1990). Although we envision that these data will be used in highly complex space-time models to observe, analyze, and measure a host of land surface process and biophysical interrelationships (see Asrar and Dozier, 1994), there are a number of vexing questions that must be addressed on how we approach the use of such multiscaled data. Outside of the mechanical difficulties that need to be overcome in manipulating multiscaled data, of paramount concern is how to analyze such complex data sets. What tools do we use to robustly maximize the information content within and amongst different remote sensing data sets and assess highly complex interrelationships between these data sets using an integrated approach?

2. Geospatial Analysis

Analytical techniques in remote sensing that explicitly consider the spatial structure of imaged features have primarily been measures of image texture (Haralick, et al., 1973; Chen, et al, 1997). Gray-tone spatial-dependence or co-occurrence matrices provide the basis for a number of measures including range, variance, standard deviation, entropy, or uniformity within a moving window. These measures have been shown (Carr and Miranda, 1998) to be a potentially useful means for image classification. Woodcock and Strahler (1987) proposed the use of local variance as an indication of the appropriate classification technique and spatial resolution for a given application.